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MULTI-STAGED HEATING SYSTEM FOR FABRICATING MICROELECTRONIC DEVICES

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BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention generally relates to a system and a method for fabricating microelectronic devices and, more specifically, a system and a method for controlling the temperature of a fluid used to process a microelectronic topography prior to and during a fabrication step.

2. Description of the Related Art

The following descriptions and examples are not admitted to be prior art by virtue of their inclusion within this section.

Electroless plating is a process for depositing materials on a catalytic surface from an electrolyte solution without an external source of current. An advantage of an electroless deposition process is that it can be selective, i.e., the material can be deposited only onto areas that demonstrate appropriate chemical properties. In addition, electroless deposition techniques are favorable for depositing materials into deep holes within the topography that cannot be uniformly covered by other deposition techniques, such as sputtering and evaporation, for example. As such, an electroless deposition process may be advantageous for depositing a metal using a damascene process. One common drawback of existing electroless deposition processes and apparatuses is, however, low deposition rates. For example, a typical electroless deposition process does not exceed 100 nm/min. The deposition rate of an electroless process is generally dependent on the material to be deposited and, therefore, may be much lower than 100 nm/min in some cases. For instance, the deposition rate of a cobalt-tungsten-phosphorus layer may be less than approximately 20 nm/min.

In general, the deposition rate of an electroless process may depend on characteristics of the activated areas, such as profiles of the exposed surfaces. In some embodiments, the deposition rate of an electroless process may further depend on the temperature of the solution used to deposit the material. In particular, the deposition rate of an electroless process may generally increase with increases in temperature of the deposition solution. Many electroless deposition solutions, however, tend to decompose at high temperatures, leading to significant non-uniformities in the deposited material. In particular, the decomposition of a solution may cause the deposition rate of an electroless deposition process to vary across a topography or may halt the deposition process entirely.

In either case, the deposition solution needs to be replenished in order to prevent such a disruption in the deposition process. More specifically, the deposition solution needs to be replenished periodically due to the consumption of the components within the solution. Such a replenishment process, however, may cause non-uniformities in the deposition process. In particular, the replenishment of a solution within a process chamber may cause the temperature of the solution to fluctuate, causing the deposition rate to vary. In some cases, such temperature fluctuation issues are resolved by replenishing the chamber with a solution which is stored at the desired process temperature. Storing the solution at the desired process temperature prior to introducing it into the chamber, however, may undesirably advance the decomposition of the solution, resulting in a shortened processing life. Consequently, the solution, in such an embodiment, may need to be replenished at a high flow rate. As a result, a vast of amount of solution may be used, increasing production and waste disposal costs of the process.

As such, it would be advantageous to develop a system and a method for delivering a fluid into a chamber used to process a microelectronic topography without disrupting the rate of the fabrication step. More specifically, it would be beneficial to develop a system and a method which prepare a fluid for delivery into a chamber by

regulating the temperature of the fluid at different stages prior to being introduced into the chamber. In particular, it would be advantageous to have a system and a method which minimize the temperature fluctuation of the fluid within the chamber upon replenishment of the fluid, while also minimizing the variation of components within the fluid. Such a system and method may be particularly advantageous for processes associated with an electroless deposition process.

SUMMARY OF THE INVENTION

The problems outlined above may in large part be addressed by a system and a method for delivering a fluid into a chamber that is used to process microelectronic topographies. In particular, a system and a method are provided which control the temperature of a fluid used to process a microelectronic topography prior to and during a fabrication step of the topography. In general, the system may include a chamber configured to process one or more wafers for the fabrication of microelectronic devices. In some cases, the chamber may be particularly configured to conduct an electroless deposition process, including but not limited to any processes performed prior to, during, or subsequent to an electroless deposition process. In particular, the chamber may be configured to conduct etching, activating, depositing, rinsing and/or cleaning steps associated with an electroless deposition process. In other cases, the chamber may additionally or alternatively be configured to conduct processes other than steps associated with an electroless deposition process.

In any case, the system may further include a plurality of reservoirs adapted to store a fluid used to process wafers in the chamber. Such a plurality of reservoirs may be serially coupled to the chamber via a plurality of intervening pipes such that the system may be adapted to transport the fluid from the plurality of reservoirs to the chamber. In some cases, the system may be further adapted to transport the fluid from the chamber to one or more of the plurality of reservoirs. In addition or alternatively, the system may be adapted to circulate the fluid between at least two of the plurality of reservoirs. In some

embodiments, the system may include one or more additional process chambers coupled to at least one of the plurality of reservoirs.

In any case, the system may include a plurality of temperature controllers positioned such that the chamber and the plurality of reservoirs are characterized into at least three different zones based upon adaptations of the temperature controllers to maintain the fluid within distinct temperature ranges in the respective zones while processing the wafers. In particular, the system may include one or more devices adapted to maintain the fluid supplied to the chamber within a first temperature range, while another set of devices may be adapted to maintain the fluid residing in a first set of the plurality of reservoirs within a second temperature range. In addition, a second set of the plurality of reservoirs, distinct from the first set, may be used to maintain the fluid residing therein within a third temperature range. Additional sets of the reservoirs may be used to characterize other temperature zones of the system as well, depending on the design specifications of the apparatus. In other cases, however, the system may be specifically adapted to only characterize three different zones. In any case, the plurality of temperature controllers may be positioned such that the different zones are arranged in ascending order based upon their respective temperature ranges. In such an embodiment, the zone in which the chamber is included may have the highest temperature range. Alternatively, the plurality of temperature controllers may be positioned such that the different zones may be arranged in descending order based upon their respective temperature ranges. In such an embodiment, the zone in which the chamber is included may have the lowest temperature range.

In any case, the temperature ranges of the different zones of the system may be distinct from each other. In some embodiments, the temperature range of the zone including the process chamber may be higher than the temperature range of the zone including the first set of reservoirs. In addition or alternatively, the temperature range including the first set of reservoirs may be higher than the temperature range of the zone including the second set of reservoirs. In yet other embodiments, the temperature range

of the zone including the process chamber may be lower than the temperature range of the zone including the first set of reservoirs, which may be lower than the temperature range of the zone including the second set of reservoirs. In any case, the system may, in some embodiments, be used for an electroless deposition process, as noted above. In such an embodiment, an exemplary temperature range for the zone farthest away from the process chamber may be between approximately 42° C and approximately 50° C, while the temperature range for the zone arranged directly adjacent to the zone including the process chamber may include temperatures between approximately 70° C and approximately 95° C. An exemplary temperature range for the zone including the process chamber may include temperatures between approximately 95° C and approximately 115° C. Other temperature ranges, however, may be used for the different respective temperature ranges, depending on the design specifications of the fabrication step and the operating parameters of the fluid.

The temperature controllers may be arranged in a variety of locations within the system in order to achieve the characterization of distinct zones of temperature ranges. For example, in some embodiments, one or more of the temperature controllers may be arranged within and/or about the process chamber. In addition or alternatively, one or more of the temperature controllers may be coupled to a fluid inlet of the chamber. In yet other embodiments, one or more of the temperature controllers may be arranged within one of the plurality of reservoirs or within one of a plurality of pipes configured to transport the fluid from the plurality of reservoirs to the chamber. In any case, the plurality of temperature controllers may include any type of mechanism with which to control the temperature of a fluid. For example, in some cases, the temperature controllers may include a heater or more specifically, an infrared heater. In other embodiments, the temperature controllers may additionally or alternatively include a cooler.

A method for delivering a fluid to a chamber configured to process wafers for the fabrication of microelectronic devices is also contemplated herein. In particular, a method is provided which includes storing a fluid, used to process microelectronic topographies, within a storage tank of a microelectronic fabrication apparatus. Such a step may include controlling the temperature of the fluid within a preliminary temperature range. The method may further include transporting the fluid from the storage tank to an intermediate tank of the microelectronic fabrication apparatus. In some cases, the step of transporting the fluid from the storage tank to the intermediate tank may include circulating the fluid between the storage tank and intermediate tank. In other cases, the transportation of the fluid may be simply include delivering the fluid from the storage tank to the intermediate tank without a recirculation loop back to the storage tank. In either embodiment, the method may include controlling the temperature of the fluid within the intermediate tank to be within a transitional temperature range which is distinct from the preliminary temperature range of the storage tank.

As noted above, the method may include delivering the fluid to a process chamber of the microelectronic fabrication apparatus. In particular, the method may include transporting the fluid from the intermediate tank to the process chamber. In some cases, the method may include recirculating the fluid from the chamber to at least one of the intermediate and storage tanks. In other embodiments, however, the fluid from the chamber may be disposed. In either case, the method may include controlling the temperature of the fluid within the process chamber to be within a process temperature range which is distinct from the preliminary and transitional temperature ranges of the storage and intermediate tanks, respectively. In general, the steps of controlling the temperature within the intermediate tank or process chamber may include heating and/or cooling the fluid.

There may be several advantages to using the system and methods described herein. For example, a system is provided which is configured to deliver a fluid into a chamber used to process a microelectronic topography without substantially altering the

temperature of the fluid within the chamber. In this manner, a system and method are provided which allows a fluid to be introduced into a processing chamber without disrupting the rate of fabrication of a microelectronic device. For instance, a deposition solution for an electroless deposition process may be replenished without having the temperature of the solution vary within the chamber. As a result, a substantially uniform layer may be deposited. In addition, the system and method described herein may advantageously minimize the amount of fluid used to process the topography by optimizing the temperature and time the fluid is heated prior to being introduced in the chamber. Consequently, material and waste disposal costs associated with the process may be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the accompanying drawings in which:

Fig. 1a depicts a schematic diagram of a microelectronic fabrication system in a storage mode of operation;

Fig. 1b depicts a schematic diagram of the microelectronic fabrication system illustrated Fig. 1a in a pre-process mode of operation;

Fig. 1c depicts a schematic diagram of the microelectronic fabrication system illustrated Fig. 1a in process mode of operation; and

Fig. 2 depicts a flow chart of a method for delivering a fluid to a process chamber of the system illustrated in Figs. 1a-1c.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the present invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning now to the drawings, an exemplary embodiment of a system configured to prepare a fluid for optimum use within a microelectronic fabrication chamber is illustrated in Figs. 1a-1c. In particular, Figs. 1a-1c illustrate a system adapted to control the temperature of a fluid used to process a microelectronic topography prior to and during a fabrication step of the topography. Such an adaptation may be used to minimize the thermal fluctuations of the fluid within the chamber such that the reaction rate at which the fabrication step is conducted may be maximized and the uniformity of the process may be substantially stable. In addition, the adaptation of the system may be used to optimize the life of the fluid such that material and waste disposal costs may be minimized.

As shown in Figs. 1a-1c, the system is designated, as a whole, by reference numeral 20 and includes process chamber 22. In general, process chamber 22 may be configured to process one or more wafers for the fabrication of microelectronic devices. More specifically, process chamber 22 may be configured to conduct one or more processing steps, such as depositing, etching, activating, polishing, cleaning, rinsing, drying, or any combination of such processes associated with the fabrication of microelectronic devices. As such, process chamber 22 may be adapted to produce conditions which may be necessitated by one or more steps of a fabrication process. In particular, process chamber 22 may be adapted to generate environments with pressures

below, at, or above atmospheric pressure as well as temperatures ranging between approximately -20° C and approximately 800° C. In addition, process chamber 22 may be adapted to process a microelectronic topography with a fluid in any state of matter known to be used in the microelectronic fabrication industry for a respective process step. As such, process chamber 22 may be adapted to treat a microelectronic topography with a liquid, gas, or plasma, including gases in a standard state or an excited state (i.e., a photon-activated gas state).

In a preferred embodiment, process chamber 22 may be used for processes associated with an electroless deposition process, including any processes performed prior to, during, and/or subsequent to an electroless deposition process. For example, in some cases, process chamber 22 may be used to activate a surface of a microelectronic topography such that a layer may be subsequently deposited using an electroless deposition solution within process chamber 22 or within a different process chamber. In addition or alternatively, process chamber 22 may be used for polishing, rinsing, and/or cleaning an electrolessly deposited layer as well as depositing a cap layer upon the electrolessly deposited layer. In yet other embodiments, process chamber 22 may simply be used for electroless deposition of a layer. In any case, process chamber 22 may be additionally or alternatively used for processes not associated with an electroless deposition process as well.

In general, process chamber 22 may have a plurality of components arranged therein and coupled thereto. For example, process chamber 22 may include a substrate holder, a plurality of inlets and outlets, and a loading port as well as any other components which may be used to process a microelectronic topography. Such a plurality of components is not illustrated in Figs. 1a-1c to simplify the drawing illustrations. In general, the system and method described herein are not restricted by the configuration of process chamber 22. As such, any process chamber configured for the fabrication of microelectronic devices may be included within system 20. Exemplary configurations of process chambers that may be used for process chamber 22 are

described in U.S. patent application numbers 10/103,015; 10/242,331; 10/369,878; 10/247,895; and 10/299,074, which are incorporated by reference as if fully set forth herein.

As shown in Figs. 1a-1c, system 20 may further include intermediate tank/s 24 and storage tank/s 26 serially coupled to process chamber 22. In general, intermediate tank/s 24 and storage tank/s 26 may be adapted to store a fluid used to process a microelectronic topography within process chamber 22. As noted above, process chamber 22 may be used for any microelectronic fabrication process, including but not limited to, depositing, etching, activating, polishing, cleaning, rinsing, drying, or any combination of such processes. As such, intermediate tank/s 24 and storage tank/s 26 may be adapted to store any fluid, including a liquid or a gas, which is used for the fabrication of a microelectronic device. In some cases, the fluid stored within include intermediate tank/s 24 and storage tank/s 26 may be associated with processes that treat a microelectronic topography prior to, during, and/or subsequent to an electroless deposition process. For example, the fluid may be an electroless deposition solution. In other embodiments, the fluid may used for the treatment of a wafer prior to or subsequent to an electroless deposition process. In yet other cases, the fluid stored within include intermediate tank/s 24 and storage tank/s 26 may be used for processes other than those associated with an electroless deposition process.

In general, intermediate tank/s 24, storage tank/s 26 and process chamber 22 may each include one or more reservoirs. In particular, process chamber 22 may include one or more reservoirs coupled in parallel to intermediate tank/s 24. In this manner, intermediate tank/s 24 and storage tank/s 26 may be used to supply a fluid to a single process chamber or a plurality of process chambers. In cases in which one or both of intermediate tank/s 24 and storage tank/s 26 include a plurality of reservoirs, the reservoirs may either be serially coupled to each other or may be arranged in parallel. Alternatively stated, intermediate tank/s 24 may, in some embodiments, include a plurality of reservoirs coupled in series or in parallel to each other. Similarly, storage

tank/s 24 may additionally or alternatively include a plurality of reservoirs coupled in series or in parallel. In yet other embodiments, one or both of intermediate tank/s 24 and storage tank/s 26 may include a single reservoir. In any case, system 20 may include one or more other "sets" of intermediate and storage tanks serially coupled to each other such that other fluids may be supplied to one or more process chambers of system 20 in a manner similar to the method described below in reference to intermediate tank/s 24 and storage tank/s 26. As used herein, a "set" of intermediate and storage tanks may generally refer to one or more storage tanks serially coupled to one or more intermediate tanks for the delivery of a particular fluid to one or more process chambers.

In any case, the primary distinction between intermediate tank/s 24 and storage tank/s 26 are their adaptations to maintain the fluid residing therein within two distinct temperature ranges as described in more detail below. Another matter of distinction between intermediate tank/s 24 and storage tank/s 26, however, may also be the volume of fluid each is configured to hold. In particular, storage tank/s 26 may be configured to hold a larger volume of liquid than intermediate tank/s 24 in some embodiments. For example, in some cases, storage tank/s 26 may be adapted to hold between approximately 30 liters and approximately 100 liters of fluid, while intermediate tank/s 24 may be adapted to store between approximately 10 liters and approximately 30 liters. Although intermediate tank/s 24 and storage tank/s 26 may be adapted for larger or smaller volumes of fluid depending on the design specifications of the system, the relative amounts of fluid storage tank/s 26 and intermediate tank/s 24 are adapted to hold preferably decrease with the proximity of the tanks to process chamber 22 in such an embodiment. Consequently, in some embodiments, one or both of intermediate tank/s 24 and/or storage tank/s 26 may have a plurality of reservoirs of different volumes serially arranged in order of their volumes. In other embodiments, however, one or both of intermediate tank/s 24 and/or storage tank/s 26 may have a plurality of reservoirs having substantially similar volumes as each other. In yet other cases, intermediate tank/s 24 may not be configured to hold a smaller amount of fluid than storage tank/s 26, but rather may be configured to store a similar amount of fluid.

In any case, process chamber 22 is preferably configured to hold a smaller volume of fluid than intermediate tank/s 24. For example, in the aforementioned embodiment in which fluid volumes for intermediate tank/s 24 and/or storage tank/s 26 are recited, process chamber 22 may be adapted to hold approximately 2 liters or less of fluid. In other cases, process chamber 22 may be adapted to hold larger or smaller volumes of fluid, depending on the design specifications of the device. In any case, scaling down the reservoir volumes between storage tank/s 24 and process chamber 22 may be advantageous for minimizing the advancement of fluid decomposition as described in more detail below. In particular, changing the temperature of relatively small volumes of fluid will generally be easier to accomplish the process of changing the temperature of the fluid to a desired temperature for the fabrication process in process chamber 22 while minimizing the advancement of the fluid decomposition.

As shown in Figs. 1a-1c, intermediate tank/s 24 and storage tank/s 26 may be serially coupled to process chamber 22 by intervening pipes 28. As noted above, intermediate tank/s 24 and storage tank/s 26 may be adapted to store a fluid used to process a microelectronic topography. Intervening pipes 28, on the other hand, may be used to transport the fluid between storage tank/s 26, intermediate tank/s 24, and process chamber 22 via pumps 30. It is noted that although pipes 28 may be adapted to store some of the fluid during certain moments of the process, tank/s 24 and 26 are clearly distinct from pipes 28 in that the tanks are configured to store a considerable larger amount of fluid than pipes 28. In particular, tank/s 24 and 26 may be distinguished as reservoirs, while pipes 28 may be distinguished as passageways. It is further noted that system 20 may be adapted to provide fluids other than the fluid stored in intermediate tank/s 24 and storage tank/s 26 to process chamber 22 in some embodiments. In particular, system 20 may be adapted to supply a plurality of fluids either simultaneously or sequentially into process chamber 22. Consequently, system 20 may include a plurality of reservoirs and supply lines other than intermediate tank/s 24, storage tank/s 26, and intervening pipes 28 for supplying fluids to process chamber 22. Such a plurality

of other reservoirs and supply lines are not illustrated Figs. 1a-1c in order to simply the drawing illustrations.

Similarly, Figs. 1a-1c do not illustrate other components that may enhance the operation of system 20 in order to simplify the drawing illustrations. For example, in some embodiments, system 20 may include filters with which remove foreign matter from the fluid. In general, filters may be arranged within any portion of system 20, including intermediate tank/s 24, storage tank/s 26 and/or pipes 28. Alternatively, system 20 may not include filters. In either case, system 20 may sometimes include process control devices, such as temperature and/or pressure gauges, within pipes 28, storage tank/s 26, intermediate tank/s 24, and/or process chamber 22. In addition, system 20 may be adapted to control the flow rate and time at which a fluid is transferred between tank/s 24 and 26 and/or supplied to process chamber 22. As such, pipes 28 may include solenoid valves in some cases. Operation of the solenoid valves as well as other components within system 20 may be controlled through central processing unit (CPU) 46 as described in more detail below.

In general, fluid supplied to process chamber 22 may be removed through exhaust ports of the chamber. In some embodiments, the outlet ports may discharge the fluid to a waste stream to be disposed. In other embodiments, however, one or more of the outlet ports may serve to recycle the process fluid back to intermediate tank/s 24 and/or storage tank/s 26 as described in more detail below. In this manner, the fluid may be reused such that material and disposal costs may be minimized. In some cases, the recirculation line may include a filter such that tank/s 24 and/or 26 are not contaminated with particles removed from process chamber 22. For example, in some embodiments, the recirculation line may include a magnetic filter such that magnetic materials may be removed from the recirculated fluid. Other types of filters, however, may also or alternatively be included in the recirculation line from process chamber 22 to intermediate tank/s 24 and/or storage tank/s 26. The inclusion of a magnetic filter may be particularly advantageous in embodiments in which the size of magnetic particles is sufficiently low to allow them to

flow through non-magnetic filter mediums. In some embodiments, the inclusion of a magnetic filter may be beneficial for embodiments in which an electroless deposition solution is recirculated from process chamber 22. In particular, a magnetic filter may be used to remove particulate metal from the recirculated fluid, which may otherwise serve as a catalyst to consume the components of the fluid, reducing the life of the solution. Another advantage of using a magnetic filter is that particles may be removed without affecting the fluid flowrate through the recirculation line.

As noted above, system 20 may be configured to control the temperature of a fluid prior to and during the fabrication step of a microelectronic device within process chamber 22. In particular, system 20 may include temperature controllers 36 positioned such that process chamber 22, intermediate tank/s 24, and storage tank/s 26 are characterized into at least three different zones based upon the adaptations of temperature controllers 36 to maintain the fluid within distinct temperature ranges in the respective zones while processing the wafers. More specifically, one or more of temperature controllers 36 may be positioned to maintain the fluid supplied to process chamber 22 within a first temperature range, while another set of temperature controllers 36 may be positioned to maintain the fluid residing in intermediate tank/s 24 within a second temperature range distinct from the first temperature range. In addition, storage tank/s 26 may be used to maintain the fluid residing therein within a third temperature range distinct from the first and second temperature ranges. In this manner, temperature controllers 36 may be positioned such that process chamber 22, intermediate tank/s 24, and storage tank/s 26 are respectively characterized into zones 40, 42, and 44 as shown in Fig. 1a.

As used hereinafter, the term "zone" may generally refer to a region of system 20 having components such as reservoirs and adjoining pipes that are configured to maintain a fluid within a particular temperature range. As such, "zone 44," as used herein, may generally refer to the zone including process chamber 22, while "zone 40" may generally refer to the zone farthest away from process chamber 22 and including at least a portion

of storage tank/s 26 and "zone 42" may refer to a zone in between zones 40 and 44 and including at least a portion of intermediate tank/s 24. In some embodiments, temperature controllers 36 may be positioned to characterize system 20 to have more than three zones. More specifically, storage tank/s 26 and intermediate tank/s 24 may be configured into more than two zones, particularly in embodiments in which one or both of storage tank/s 26 and intermediate tank/s 24 include a plurality of reservoirs. Embodiments in which system 20 includes more than three distinct zones may be particularly advantageous for cases in which the fluid has a relatively large temperature differential to overcome from the storage tank arranged farthest from process chamber 22 to the process chamber. In particular, a system with more than three distinct zones may offer a manner with which to more easily and more efficiently change the temperature of the fluid for treatment of a topography in process chamber 22. On the contrary, in some embodiments, it may be advantageous for system 20 to be limited to three zones in order to simplify the configuration of the system and the number of components and controls necessary to operate such a system.

In general, temperature controllers 36 may be arranged in a variety of locations within system 20 in order to achieve the characterization of zones 40, 42, and 44 and any zones in between zones 40, 42, and 44. For example, in some embodiments, one or more of temperature controllers 36 may be arranged within and/or about process chamber 22. In particular, one or more of temperature controllers 36 may be incorporated into any component arranged within process chamber 22, such as a wafer chuck configured to hold one or more wafers or a fluid inlet of the chamber. In addition or alternatively, one or more of temperature controllers 36 may be coupled to the exterior of process chamber 22. In any case, one or more of temperature controllers 36 may further be arranged within intermediate tank/s 24 and/or within one or more of the intervening pipes as shown in Figs. 1a-1c. In particular, one or more temperature controllers 36 may be arranged within intermediate tank/s 24 and/or the intervening pipes within zones 42 and 44 and any zones in between zones 40, 42, and 44. In some cases, one or more of temperature controllers 36 may be additionally arranged within storage tanks/ 26 and/or within one or more of the

intervening pipes within zone 40. In other embodiments, however, temperature controllers 36 may not be positioned within zone 40. In particular, the temperature of the fluid within storage tank/s 26 and adjoining pipes may alternatively be maintained by the environment in which system 20 is arranged.

In any case, temperature controllers 36 may, in some embodiments, be positioned such that zones 40, 42, and 44 and any zones in between zones 40, 42, and 44 are arranged in ascending order based upon their respective temperature ranges. In such an embodiment, zone 44 including process chamber 22 may have the highest temperature range. More specifically, the temperature range of zone 44 may be higher than the temperature range of zone 42 and the temperature range of zone 42 may be higher than zone 40. In this manner, temperature controllers 36, in such an embodiment, may be adapted to heat the fluid in stages as it traverses between storage tank/s 26, intermediate tank/s 24 and process chamber 22. The adaptation to heat the fluid residing within process chamber 22, intermediate tank/s 24 and sometimes storage tank/s 26 may, in some embodiments, be advantageous for improving the reaction rate of the fabrication process conducted within process chamber 22. For example, in an embodiment in which an electroless deposition process is conducted within process chamber 22, heating the deposition solution may advantageously increase the deposition rate of the process. Reaction rates of other microelectronic fabrication processes may benefit from heating as well.

In an alternative embodiment, temperature controllers 36 may be positioned such that the zones 40, 42, and 44 and any zones in between zones 40, 42, and 44 are arranged in descending order based upon their respective temperature ranges. In such an embodiment, zone 44 may have the lowest temperature range. More specifically, the temperature range of zone 44 may be lower than the temperature range of zone 42 and the temperature range of zone 42 may be lower than the temperature range of zone 40. Consequently, temperature controllers 36, in such an embodiment, may be adapted to cool the fluid in stages as it traverses between storage tank/s 26, intermediate tank/s 24

and process chamber 22. Similar to the adaptation to heat a fluid, the adaptation to cool the fluid residing within process chamber 22, intermediate tank/s 24 and sometimes storage tank/s 26 may, in some embodiments, be advantageous for improving the fabrication process conducted in process chamber 22.

In other embodiments, temperature controllers 36 may be positioned such that the zones 40, 42, and 44 and any zones in between zones 40, 42, and 44 are arranged in neither ascending or descending order but rather, in a random order based upon their respective temperature ranges. In such an embodiment, the temperature ranges of each zone is still preferably distinct, but the temperature range of zone 44 may be higher or lower than the temperature range of zone 42 and the temperature range of zone 42 may respectively be lower or higher than the temperature range of zone 44. Such mixed order of temperature ranges may be advantageous for processes in which the chemical composition of a fluid is altered at a particular temperature, but may be used at a lower or higher temperature after such an alteration.

In any case, temperature controllers 36 may include any type of mechanism with which to control the temperature of a fluid. For example, in some cases, temperature controllers 36 may include heaters and in some embodiments, specifically infrared heaters. An infrared heater may specifically offer a manner with which to efficiently and uniformly heat a fluid. In other embodiments, temperature controllers 36 may include coolers. In yet other cases, temperature controllers 36 may include heaters and coolers. For example, as noted above, in some embodiments it may be advantage to heat a fluid to a desired temperature to enhance the deposition rate of the fabrication process. In such an embodiment, however, it also may be beneficial to be able to cool the fluid such that deposition process may be immediately terminated, allowing more control over the amount deposited upon the substrate. In addition or alternatively, the fluid within process chamber 22, as described in more detail below, may, in some embodiments, be recirculated back to one or both of intermediate tank/s 24 and storage tanks 26 during or subsequent to a fabrication process. In such an embodiment, it may be advantageous to

have a temperature controller coupled to the recirculation pipe such that the temperature of the fluid may be cooled back to the temperature specified for the zone to which it is returning. In any case, temperature controllers 36 may be adapted to monitor the temperature of a fluid and, therefore, may further include thermocouples in some embodiments.

In general, the temperature ranges for zones 40, 42, and 44 and any zones in between zones 40, 42, and 44 may depend on the fabrication step to be conducted, the operating parameters of the fluid and the design specifications of the system. For example, exemplary temperature ranges for a deposition solution for an electroless deposition process may be approximately 42° C to approximately 50° C for zone 40, approximately 70° C to approximately 95° C for zone 42, and approximately 95° C to approximately 115° C for zone 44. Other temperature ranges, however, may be maintained for the different respective zones as well. For example, in some embodiments, an electroless deposition solution may be maintained at or near room temperature in zone 44 in order to maximize the uniformity of the deposition. It is noted that although zones 40, 42, and 44 and any zones in between zones 40, 42, and 44 are distinguished by their different temperature ranges, the temperature ranges of the zones may or may not overlap. In particular, the reference of "distinct temperature ranges" merely refers to different breadths of temperatures and/or higher or lower ranges of temperatures of the different zones.

As noted above, controlling the temperature of a fluid to be within different temperature ranges at different stages within system 20 may be advantageous for preparing the fluid for optimum use within process chamber 22. In particular, maintaining a fluid in zone 40 within a temperature range which does not substantially advance the life and/or change the composition of the fluid may be advantageous for storing the fluid. In addition, maintaining the fluid in zone 44 within a temperature range which improves the reaction rate and/or uniformity of the fabrication step conducted within process chamber 22 may be advantageous for enhancing the fabrication of

microelectonic devices. Furthermore, maintaining the fluid in zone 42 within a temperature range in between the storage temperature range and the desired process temperature range of respective zones 40 and 44 may allow the fluid to be more easily altered to the desired process temperature upon replenishing the fluid within process chamber 22 without substantially advancing the life of the fluid. In particular, the temperature of the fluid may be altered to the desired temperature range more efficiently than in an embodiment in which the temperature of the fluid is directly converted from its storage temperature to the desired process temperature. As a result, temperature fluctuations of the fluid within process chamber 22 may be minimized or prevented entirely. Moreover, maintaining the fluid at such an intermediate temperature may prolong the life of the fluid since the amount of time the fluid is at such a temperature is reduced as compared to an embodiment in which a fluid is stored at the desired process temperature prior to being introduced into process chamber 22.

In some cases, system 20 may further include central processing unit (CPU) 46 configured to control operation of system 20. In particular, system 20 may include a dedicated microprocessor-based controller or a general-purpose computer to automate the operations of system 20. Consequently, the method described in reference to Fig. 2 below may, in some embodiments, be a computer-implemented method. As described below, CPU 46 may be used to control a variety of components within system 20. In general, CPU 46 may be coupled to the components of system 20 which it is configured to control. Such individual connections to the components, however, are not illustrated Figs. 1a-1c to simplify the illustrations of system 20. Rather, CPU 46 is shown coupled to system 20 by a dotted line to show a general connection to the components included within system 20.

In some cases, CPU 46 may be configured to control the operation of temperature controllers 36. In particular, CPU 46 may be configured to regulate the use of temperature controllers 36 such that the temperature of the fluid within zones 40, 42, and 44 and any zones in between zones 40, 42, and 44 may be adjusted to be within the

specified temperature ranges of the zones. CPU 46 may be adapted to control the operations of process chamber 22 as well, including but not limited to the loading and unloading of wafers within the chamber, the temperature and pressure of the chamber, as well as the introduction and disposal of fluids from the chamber.

In some cases, CPU 46 may be configured to control the opening and closing of the valves along intervening pipes 28. In this manner, the routing of the fluid between tanks 24 and 26 and process chamber 22 may be controlled. For instance, CPU 46 may include a carrier medium with program instructions for managing the use of solenoid valves on pipes 28 such that the fluid may be routed between tanks 24 and 26 and process chamber 22 based upon the use of the fluid within process chamber 22. For example, upon starting the operation of system 20, CPU 46 may include program instructions with which to supply zone 42 with fluid from zone 40. Subsequently, CPU 46 may send a command to supply zone 44 with the fluid from zone 42. During such a sequence, CPU 46 may also send instructions to one or more of the temperature controllers 36 to maintain the temperature of the fluid within the temperature range specified for the respective zones. In some cases, CPU 46 may also send commands to regulate the flow of fluid through the outlet ports of process chamber 22. In turn, CPU 46 may be used to regulate the replenishment of fluid within process chamber 22 as well. Moreover, CPU 46 may be used to manage the recirculation of fluid within and between the reservoirs of system 20 as described in more detail below.

As shown in Figs. 1a-1c, system 20 may, in some embodiments, be configured to circulate the fluid between storage tank/s 26 and intermediate tank/s 24. In particular, system 20 may include intervening pipes 28 and valves 48 configured to circulate the fluid within storage tank/s 26 and intermediate tank/s 24 independently and between each other. Such a recirculation adaptation may, in some embodiments, be advantageous for keeping the composition of the fluid within a particular zone homogenized. In addition or alternatively, recirculating the fluid within a particular zone may aid in maintaining the fluid within a specified temperature range. For example, in an embodiment in which a

tank within the zone does not include a temperature controller but an adjoining pipe does, the fluid may have to be recirculated within the zone to maintain it within its specified temperature range. In yet other cases, the tank within the zone may include a temperature controller with which to regulate the fluid temperature. In either case, system 20 may be additionally or alternatively adapted to transport the fluid from process chamber 22 to intermediate tank/s 24 and storage tank/s 26. In particular, system 20 may be adapted to return the fluid from process chamber 22 back to preceding reservoirs for storage, particularly when the fluid has not decomposed or still has an adequate process life. The determination of whether the state of the fluid is suitable to be recycled may involve using analytical tests to evaluate the fluid or may be based on historical data of the system.

In any case, system 20 may be adapted to change the position of valves 48 based upon the mode of operation of the system. Exemplary positions of valves 48 simulating the different modes of operation for system 20 are illustrated in Figs. 1a-1c. In particular, Fig. 1a illustrates an exemplary configuration of valves 48 in a position to circulate the fluid within storage tank/s 26 without having the fluid delivered to intermediate tank/s 24 or process chamber 22. Alternatively, the fluid may be stored stagnantly in storage tank/s 26. In either case, such a mode of operation of system 20 may be suitable for embodiments in which process chamber 22 is not in operation or when process chamber 22 is being serviced.

A different mode of operation is illustrated in Fig. 1b in which the fluid is transported from storage tank/s 26 to intermediate tank/s 24. Such a mode of operation may be referred to as the "pre-process" stage or, more specifically, the stage at which the fluid is prepared for delivery to process chamber 22 but not yet delivered. Consequently, the mode of operation may likely occur prior to conducting a fabrication process within process chamber 22. In some embodiments, the fluid may be recirculated back to storage tank/s 26 from intermediate tank/s 24 during such a mode of operation. In other embodiments, however, the valve on the recirculation pipe between intermediate tank/s

24 and storage tank/s 26 (i.e., the line having the arrow directed back to storage tank/s 26) may be closed. In either case, the valve on the pipe connecting the delivery and recirculation pipes between intermediate tank/s 24 and storage tank/s 26 may be closed or open, depending on whether the fluid within storage tank/s 26 is circulated during such a mode of operation.

In some embodiments, the routing of fluid between storage tank/s 26 and intermediate tank/s may be controlled by volume sensors within intermediate tank/s 24. More specifically, the position of valves 48 may depend on the volume contained within intermediate tank/s 24 and/or process chamber 22. For example, in an embodiment in which the level sensor within intermediate tank/s 24 indicates a low volume of fluid, the valve on the delivery pipe between intermediate tank/s 24 and storage tank/s 26 may be open, while the pipe connecting the delivery and recirculation pipes between intermediate tank/s 24 and storage tank/s 26 may be closed. Once the fluid within intermediate tank/s 24 reaches a particular volume, the positions of such valves may be reversed such that the flow of fluid from storage tank/s 26 to intermediate tank/s 24 is terminated and is instead recirculated in and out of storage tank/s 26. In an alternative embodiment, the fluid within storage tank/s 26 may not be recirculated upon reaching a particular volume within intermediate tank/s 24. In any case, if the level sensor within intermediate tank/s 24 indicates a high volume of fluid, the valve on the recirculation pipe between intermediate tank/s 24 and storage tank/s 26 may be opened. A similar level sensor may be used to control flow between intermediate tank/s 26 and process chamber 22 as well, however, in other embodiments the fluid flow between intermediate tank/s 26 and process chamber 22 may be based on the degradation of the fluid during the fabrication process as described in more detail below.

Another mode of operation for system 20 may be when the fluid is delivered from intermediate tank/s 24 to process chamber 22 such that a fabrication step may be performed within the chamber. Such a mode of operation is illustrated in Fig. 1c by having the valve on the delivery pipe between the intermediate tank/s 24 and process

chamber 22 open. In general, the fluid may be delivered from intermediate tank/s 24 to process chamber 22 just prior to or at the start of the fabrication process and during times in which the fluid within process chamber 22 is being replenished. As such, in some embodiments, the valve on the delivery pipe between the intermediate tank/s 24 and process chamber 22 may be closed during the "processing" mode of system 20. In other embodiments, however, the fluid within process chamber 22 may be continually replenished. In some embodiments, the rate of replenishment and/or the position of the valve on the delivery pipe between the intermediate tank/s 24 and process chamber 22 may be based on the degradation of the fluid during the fabrication process. In particular, the routing of fluid between intermediate tank/s 24 and process chamber 22 may depend on the life of the fluid affecting the reaction rate of the process. The determination of whether the life of the fluid is suitable to for the fabrication may involve using analytical tests to evaluate the fluid during the fabrication process or may be based on historical data of the system. In any case, the valve on the pipe connecting the delivery and recirculation pipes between intermediate tank/s 24 and processing chamber 22 may be closed or open, depending on whether the fluid within intermediate tank/s 24 is circulated during such a mode of operation.

As described above, in some embodiments, the fluid may be routed back to intermediate tank/s 24 and/or storage tank/s 26 upon terminating fabrication step in process chamber 22. In particular, the fluid may be recycled back to intermediate tank/s 24 and/or storage tank/s 26 if the components within the fluid are still active to process a microelectronic topography. Such a recirculation is illustrated in Fig. 1c by having the valves on the recirculation pipes between process chamber 22, intermediate tank/s 24 and storage tank/s 26 (i.e., the lines having the arrow directed back to intermediate tank/s and storage tank/s 26, respectively) open. Although Figs. 1a-1c illustrate the recirculation pipe from process chamber 22 routed back to intermediate tank/s 24 first and then to storage tank/s 26, system 20 may alternatively have a recirculation pipe from process chamber 22 routed directly back to storage tank/s 26 or just to intermediate tank/s 24. In any case, system 20 may be adapted to alter the temperature of the fluid upon recycling

the fluid from process chamber 22. In particular, system 20 may include a temperature controller on the recycling line from the process chamber such that the temperature of the fluid may be returned to the temperature of the fluid in the tank to which it is returning. In this manner, the life of a fluid which tends to degrade while maintained at a elevated temperature may be preserved. For example, the life of an electroless deposition solution may be preserved. In other embodiments, however, the valve on the recirculation pipe between intermediate tank/s 24 and process chamber 22 may be closed.

A method for delivering a fluid to a process chamber of the microelectronic fabrication apparatus is illustrated in Fig. 2. In particular, the method may include step 70 in which a fluid, used to process microelectronic topographies, is stored within a storage tank of a microelectronic fabrication apparatus. Such a step may include controlling the temperature of the fluid within a preliminary temperature range. More specifically, microelectronic fabrication apparatus may employ one or more temperature controllers with which to control the temperature of the fluid within the storage tank within a preliminary temperature range. In yet other embodiments, the environment in which the microelectronic fabrication apparatus is operated may be adapted to maintain the fluid within the storage tank within a preliminary temperature range. For example, the microelectronic fabrication apparatus may be operated in a temperature controlled environment which has a substantially similar operating range as the preliminary temperature range. In any case, the preliminary temperature range may preferably include temperatures which do not substantially degrade the life of the fluid as compared to other temperatures at which the fluid may be maintained. For example, in an embodiment in which the fluid is an electroless deposition solution, the preliminary temperature range may include temperatures between approximately 42° C and approximately 50° C. Higher or lower and larger or smaller ranges of temperatures, however, may be used for the preliminary temperature range, depending on the fabrication process to be conducted and the operating parameters of the fluid and the design specifications of the system.

As shown in step 72, the method may further include transporting the fluid from the storage tank to an intermediate tank of the microelectronic fabrication apparatus. In some cases, step 72 may include circulating the fluid between the storage tank and intermediate tank. In other cases, the transportation of the fluid may be simply include delivering the fluid from the storage tank to the intermediate tank without a recirculation loop back to the storage tank. In either embodiment, the method may include step 74 in which the temperature of the fluid within the intermediate tank is controlled to be within a transitional temperature range which is distinct from the preliminary temperature range of the storage tank. In some cases, the transitional temperature range may be higher than the preliminary temperature range. Alternatively, the transitional temperature range may be lower than the preliminary temperature range. In either case, the transitional temperature range is preferably smaller than the preliminary temperature range such that fluctuations of the fluid temperature within the process chamber may be minimized. In addition, the transitional temperature range preferably includes temperatures which are between the preliminary temperature range and the processing temperature range described in more detail below. In this manner, the fluid to be more easily altered to the desired process temperature range upon replenishing the fluid within process chamber 22 without substantially advancing the life of the fluid.

Step 76 includes transporting the fluid from the intermediate tank to the process chamber. In some cases, step 76 may include recirculating the fluid from the chamber to at least one of the intermediate and storage tanks. In other embodiments, however, the fluid from the chamber may be disposed of after using it to process wafers within the process chamber. In either case, the method may further include step 78 in which the temperature of the fluid is controlled within the process chamber to be within a process temperature range which is distinct from the preliminary and transitional temperature ranges of the storage and intermediate tanks, respectively. In some embodiments, the process temperature range may be higher than the transitional temperature range. Alternatively, the process temperature range may be lower than the transitional temperature range. In either case, the process temperature range is preferably smaller

than the transitional temperature range such that fluctuations of the fluid temperature within the process chamber may be minimized or prevented. In addition, the process range is preferably optimized to include temperatures which offer a high reaction rate as well as a uniform treatment process.

It will be appreciated to those skilled in the art having the benefit of this disclosure that this invention is believed to provide a system and a method for controlling the temperature of a fluid used to process a microelectronic topography prior to and during the fabrication step of the topography. Further modifications and alternative embodiments of various aspects of the invention will be apparent to those skilled in the art in view of this description. For example, although the system and method provided herein are frequently described in reference to process steps conducted prior to, during, and subsequent to an electroless deposition process, the system and method are not necessarily restricted to such processes. In addition, the system and method described herein may be used for any fluid in which the temperature is preferably heated and/or cooled prior to and during a step of a microelectronic fabrication process. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the invention. It is to be understood that the forms of the invention shown and described herein are to be taken as the presently preferred embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features of the invention may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description of the invention. Changes may be made in the elements described herein without departing from the spirit and scope of the invention as described in the following claims.